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Cost-Effective and Scalable Approach to EV Battery Management: MOSFET-Based Passive Cell Balancing

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Abstract

Cell balancing is crucial for preserving battery life and protecting battery cells in order to guarantee the safe and dependable functioning of LiFePo4 batteries on electric vehicles. Because passive cell balancing is inexpensive and simple to perform, BMS routinely uses it. In the passive cell balancing procedure, resistors are used as the balancing element to eliminate excess charge in the battery. Although resistors are inefficient when used with little cells, they are necessary when using large capacity batteries. The internal resistance of MOSFETs, which is utilized as a balancing element, allows for efficient cell balancing. The need for extra balancing components is eliminated by utilizing the MOSFET's intrinsic resistance. The current through the resistance is decreased hence the power losses are minimized and the heat dissipation is also reduced thus, the battery pack temperature is also maintained in the nominal value which decreases the danger of battery damage due to temperature.

Keywords: *Battery Management System, Cell balancing, MOSFET, Lithium ferrous phosphate cells, Pack of batteries.*

1. Introduction

In the late 20th and early 21st centuries, lithium-ion batteries became widely used, which presented both new possibilities and challenges for battery management. Unbalances in the state of charge of lithium-ion batteries can cause capacity deterioration, decreased performance, and safety issues because they are sensitive to these changes. As LiFePO4 battery cells proliferated, passive cell balancing approaches began to gain importance. In passive balancing, resistors or other passive elements are connected in parallel with individual cells or groups of cells. Through the resistors, the passive balancing circuit permits extra energy to be released as heat when cells with higher voltages reach them capacity limit. Higher-voltage cells can be kept from being overcharged with the aid of this procedure. Electrical vehicles (EVs) frequently use the MOSFET approach of passive cell balancing to balance the voltage levels across individual battery cells inside a battery pack. By ensuring that each cell is charged and drained equally, this balancing technique maximizes the battery pack's overall performance and longevity. Several series-connected battery cells typically make up an electric vehicle's battery pack. These cells may show slight fluctuations in their capacities, internal

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resistances, and other properties when the battery is being charged and drained. These differences have the potential to cause imbalances over time, where some cells remain undercharged and others get overcharged. This problem is solved by passive cell balancing, which creates a parallel pathway for extra energy to move from fully charged cells to undercharged cells. The switching devices in this balancing mechanism are typically MOSFETs (Metal Oxide Semiconductor Field-Effect Transistors) because of their quick response times, great efficiency, and low power consumption. An integrated circuit (IC) for Li-Ion cell voltage monitoring, balancing, and measurement that makes use of a 12-bit SAR ADC [1]. This method's main advantage is indicated for both active and passive cell balancing procedures. Based on the board monitoring device with a UART-Wi-Fi wireless module and an Android smartphone with Wi-Fi communication technology, a real-time monitoring system for lithium-ion batteries has been demonstrated. This system can balance voltage and monitor battery temperature for both EVs and HEVs [2]. It also collects data such as battery temperature and current voltage and sends it to the phone via WiFi communication, allowing for the monitoring of battery parameters [3]. The necessity for LiFePO4 cells to be balanced was made abundantly clear by the findings of the investigation on individual cells. One solution is to use switched resistor balancing. Once a battery pack has been first balanced, switching dissipative resistor balancing is a rather efficient approach to maintain balance [4]. The efficiency of the balancing circuits can reach 94%. Along with the design of the BMS, a method for estimating SOC is presented. Battery SOC is measured using the Coulomb counting method, and SoC is estimated using the DEKF (Dual Extended Kalman Filter), which combines two extended Kalman filters [5]. An explanation of the Li-ion battery pack's principles and importance is provided. In addition to discussing the charging procedures for Li-ion batteries, this page discusses passive cell balancing with switching resistors. The comparable circuit concept and the significance of cell balancing are explained in this article. When examining the characteristics of various approaches, factors such as the Li-ion battery's balancing speed, cost, capacity to charge and discharge, application, and complexity are all taken into account. Cell balancing is a key component of the BMS that enhances battery performance [6]. The 440 V/800 V battery BMS solution, lithium ion batteries, and lithium-titanate batteries are all included in the system architecture of a 48 Volt battery system. The 400V/800V BMS block diagram are shown in Figure 1 is carefully studied, paying close attention to the accuracy of the communication networks and balancers. Additionally, this article contained information on battery cell ESD protection, thermal runaway, current metering, and cell voltage [7].

2. Design Methodology

The design technique enables the creation of a battery pack balancing circuit based on single cell tests that take into consideration the key design criteria. A cell model is not necessary. This methodology accounts for the standard deviation across cells. [8]

2.1 Testing of Single Cell

The first step is to test different cells under the conditions of the final application. The balancing mechanism was designed with the possibility of measuring different cell properties during the initial testing in mind. [9] Cell metrics including SoC, Voltage, nominal temperature, rate of charge and discharge, and change in charges across the cells are checked and recorded during the first testing processes in order to ascertain the battery conditions.

2.2 Connection of Cells

To obtain the necessary battery pack voltage, the tested cells are linked in series, parallel, or series-parallel configuration once they have been tested. The battery cells are linked together in series. [10]

2.3 Balancing Techniques

Both active and passive cell balancing techniques

are available. For passive cell balancing strategies based on the SoC balancing [11] and voltage balancing methods, several cell balancing algorithms are used. The balancing approach determines the cells' minimum voltage level or minimum SoC. The excess charge or voltage is discharged through the resistance of the balancing resistor if the cell voltage exceeds the reference level. [12]

Under balanced condition,

$$Qbat = Qn$$

Under unbalanced condition,

$$Qbat \neq Qn$$

$$SoCn = Qn / Qmax$$

It is preferable to employ passive cell balancing when the battery is charging rather than when it is discharging since it keeps the battery in an equilibrium. [13] Resistors are the balancing element in passive cell balancing; they are utilized to discharge the excess charges that are stored in the batteries. There is a limit to the balancing resistor's size. Increases in resistor size result in massive heat dissipation and often bulky balancing circuits. By including the MOSFET's internal resistance, [14] which serves as the circuit's balancing factor, this can be prevented. As a result, the circuit's overall size and compactness will both decrease. MOSFET serves as both the balancing element and the power electronic switch for regulating the discharge time.

2.4 Data Interpretation

Data abstraction and data comparison are necessary for data understanding. Acquire the data such as SoC, SoH, voltage, current, temperature of the battery pack. Utilizing the BMS, compare the current cell values with the historical data that was gathered and stored in the database. [15]

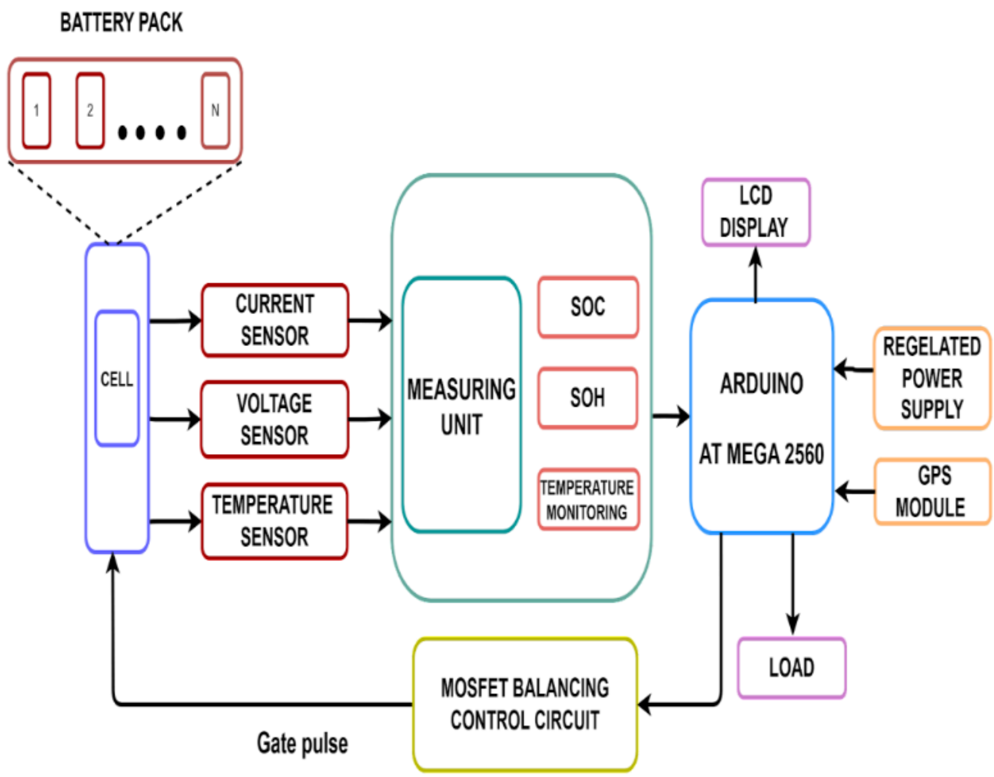

Figure 1 Block diagram

Four LiFePO4 cells make up the suggested model, and they are coupled in series to produce the necessary voltage level to drive the load. The individual voltage sensors track and measure the voltage of each cell. [16] Table 1 is shows the specification if proposed model.

Table 1 Specifications of Proposed Model

Specifications	Values
No. of cell	4 Cells
Battery pack voltage	12 Volt
Cell voltage	3.2 Volt
Cell minimum voltage	2.6 Volt
Cell maximum voltage	3.65Volt

The associated SoC level of each cell is equivalent to the observed voltage. [17] LM35 temperature sensor which is used to measure the nominal temperature of the total battery pack unit. In electric vehicles, a method called passive cell balancing is employed to balance the charge levels of individual battery cells. [18] Four battery cells are used as a model for passive balancing in order to facilitate comprehension and execution. This build uses an Arduino Mega microcontroller with LiFePO4 cells. The suggested approach works well with cell balancing techniques for electric vehicles. Proposed model for Passive cell balancing are shown in Figure 2.

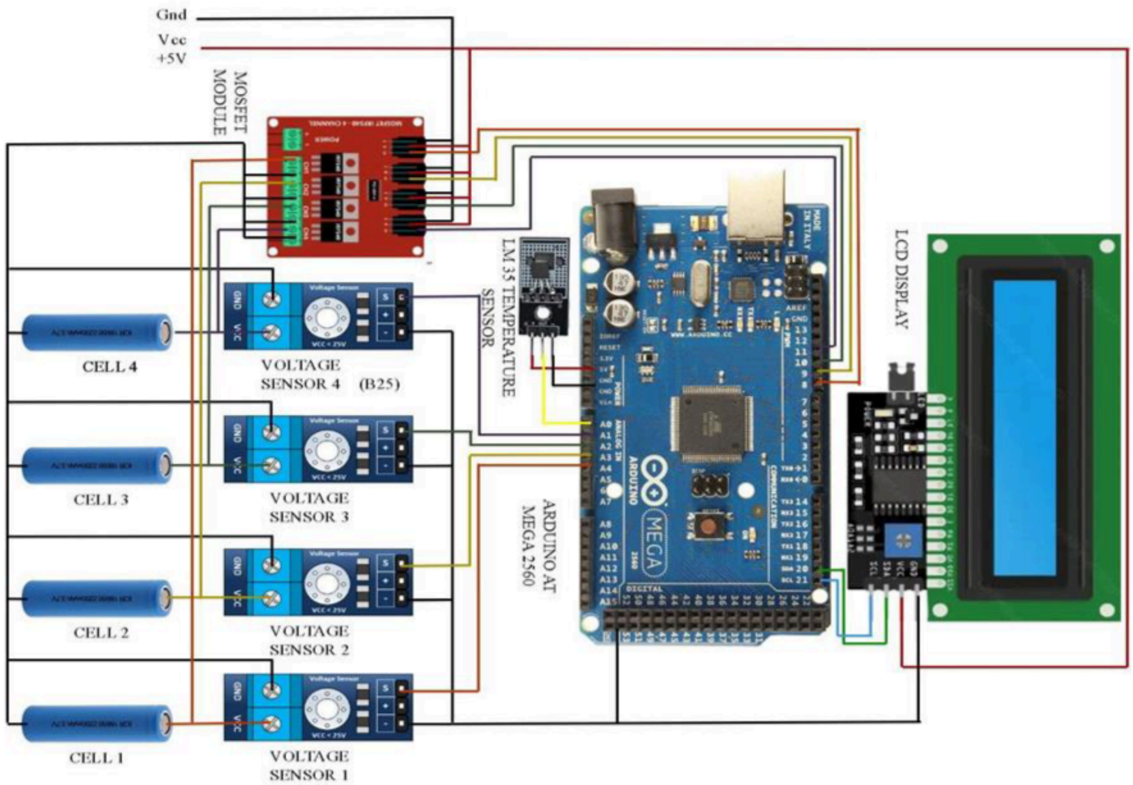

Figure 2 Proposed model for Passive cell balancing

3. Flowchart and Algorithm

The algorithm starts with the Start of conversion instruction.

Step 1: Check the voltage in each cell of the battery pack that is attached.

Step 2: Check the level of voltage of each cell.

Step 2.1: The user is informed and a warning signal is sent if the cell voltage levels are beyond the threshold value.

Step 2.2: The procedure is carried out if the threshold voltage is within the allowed range.

Step 3: Verify that the SoCs in each cell are the same.

Step 4: Make sure that every cell has the same SoCs.

Step 5: Find the lowest SoC value among the connected cells if the SoC levels of the cells differ.
Step 6: As a reference SoC, set that SoC. The reference SoC is the smallest level of SoC among the cells in passive cell balancing.
Step 7: All other cell SoC are balanced to the reference SoC by turning on the appropriate MOSFET for the relevant time interval to discharge the excess charge stored in the cell. Passive cell balancing can be accomplished in this way.
Step 8: Verify whether the battery is in optimal condition.
Step 8.1: The battery must be charged to the pack voltage level if it is not idle.
Step 8.2: If everything is perfect, the procedure is checked again starting at the first stage.
Step 9: The loop is run continually, watching the battery parameter and responding to changes in the situation.
End of conversion is done when the cells get balanced. The process of flow chart shown in Figure 3.

Figure 3 Flowchart

4. Experimental Setup

The battery cell and microcontroller are coupled by semiconductor switching devices, or MOSFETs. Higher differences in charge between individual cells are detected by the controller, which discharges other cells from higher levels of charge to the lowest levels of charge on a battery pack by taking the cell's least soc level and providing a gate pulse to the MOSFET. The auxiliary component receives this discharged charge as an input in the bms. Uninterrupted communication between the car and the user is tracked via GPS. Developed model are shown in Figure 4.

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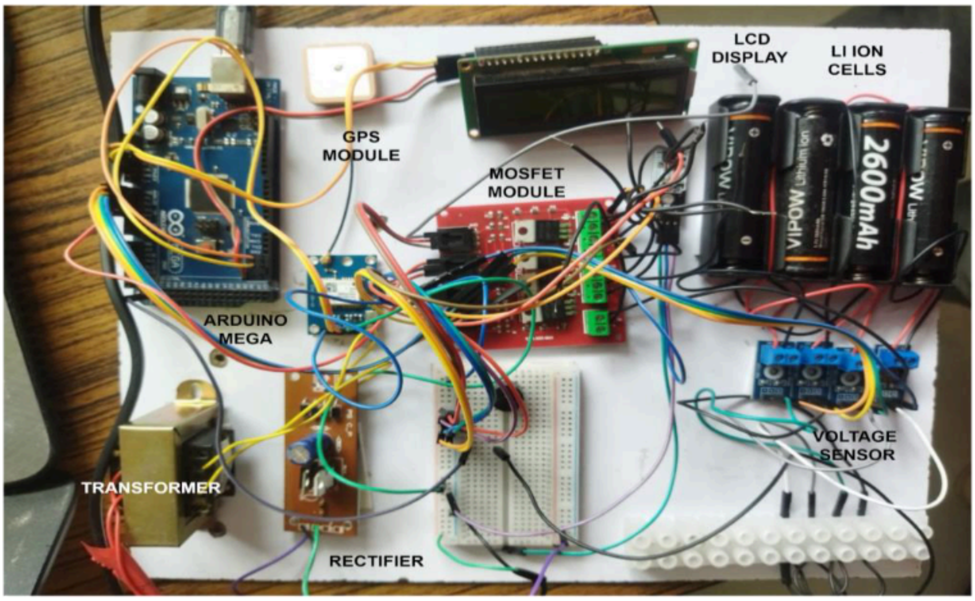

Figure 4 **Developed Model**

5. Result

5.1 Simulation

Simulations provide simplified models that replicate real-world processes, which aid in the understanding of complex systems and their behavior. This makes it possible to research how different system components interact and change over time.

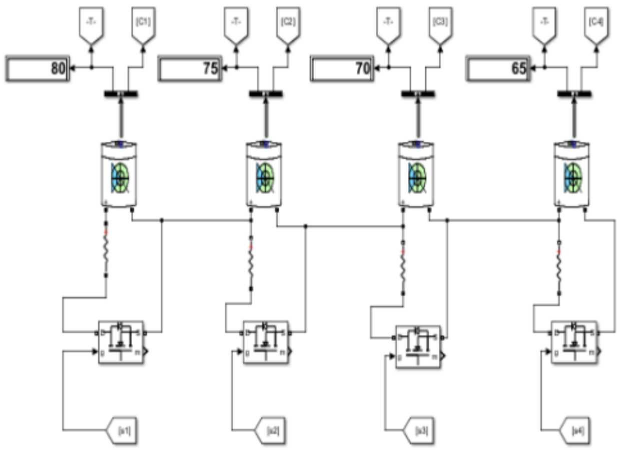

Figure 5 **Before Cell Balancing**

This is a MATLAB simulation showing the passive cell balancing of four series-connected LiFePo4 cells. The MOSFETs and the cell are connected in parallel. Prior to battery balancing, the SoCs of each cell varied. Despite the battery being out of balance, they have varying SoC levels. Figure 5,6 are shows the before and after cell balancing process.

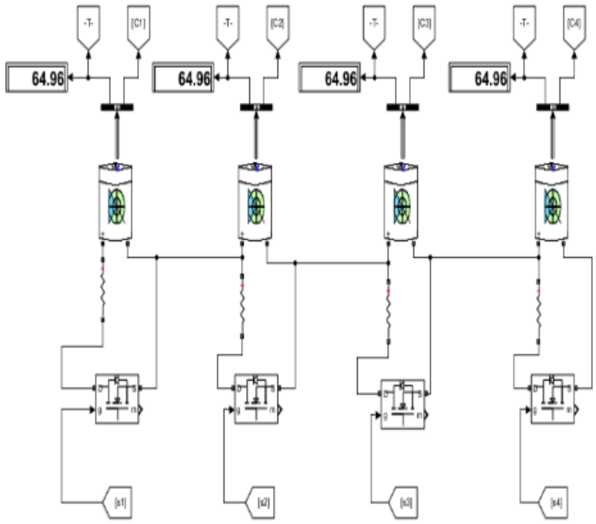

Figure 6 **After Cell Balancing**

All of the cell SoC levels are balanced to the reference cell SoC or at least once the battery's SoC levels have been balanced in the simulation. This can be accomplished by using the MOSFET's internal resistance to dissipate the excess charges in the battery cells. Passive cell balancing of LiFePO4 cells utilizing MOSFET is the name of this practice. The results of the above four cells as mentioned in "Fig 6 and 7" the charging current and SoC of cell 1, cell 2, cell 3 and cell 4 as shown below.

5.2 Output

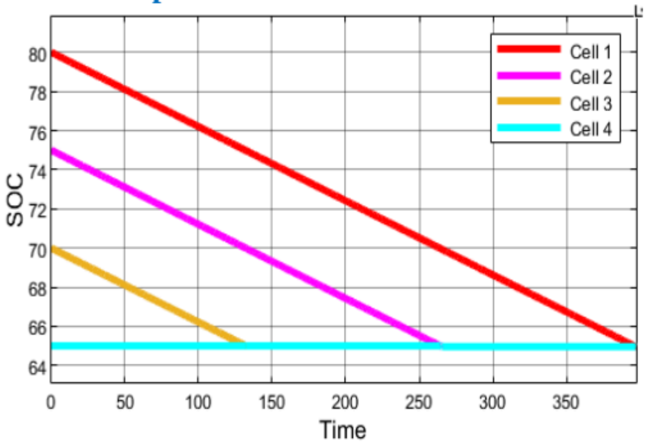

Figure 7 **SoC of Four Cells**

After employing passive cell balancing techniques to balance the cells, the values of SoC for each cell are displayed in Figure 7. The battery pack was initially out of balance and had various SoC levels (80, 75, 70, and 65), which are taken into account during the balancing procedure. Using the MOSFET, the surplus energy in the battery was released as heat in this technique. When using passive cell balancing, the cell with the lowest SoC overall is considered the reference SoC.

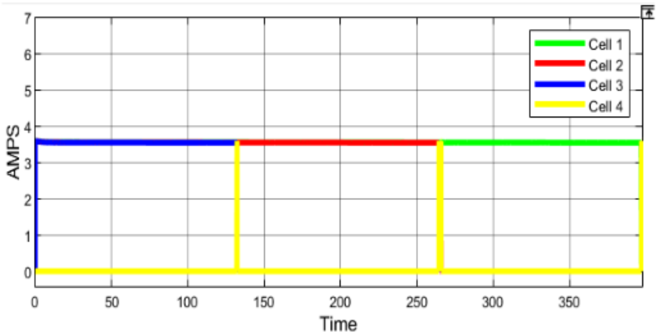

Figure 8 **Balancing Current of Four Cells**

The output result of the balancing current, or the current that is dissipated through the MOSFET, is displayed in Figure 8. The internal resistance of the MOSFET and the resistors in the simulation dissipates the remaining cell charge as heat in the suggested simulation with the lowest SoC. The battery cells are balanced by this method.

Conclusion

One way to keep each LiFePO4 cell in a battery pack operating at its maximum capacity and state of charge (SoC) is to use passive cell balancing. The benefits include a battery management system that is less sophisticated, simpler, and more affordable (BMS). Dissipating the excess charge that was held in the LiFePO4 battery cells, the resistance inside the MOSFET structure acts as the balancing resistance in passive cell balancing. The LiFePO4 cell of a battery pack can be balanced using the passive cell balancing approach by using the model that was previously provided. The recommended model has the battery capacity to maintain the cell voltage in line with the balancing voltage. The proposed model's output can be expanded to take into account the battery pack's voltage requirements. Cell balancing times in a battery pack might vary depending on the cell SoCs. Passive balancing methods have improved in effectiveness and efficiency over time. Advancements in resistor layout, design, and control algorithms have resulted in more accurate balancing and less energy waste which leads to enhancing the battery performance and the life span of the pack of pack while using this proposed model.

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